IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant :	Mark W. Wanlass, et al.	)	Group Art: 1722
		)	
Serial No. :	10/526,785	)	Examiner: SONG, Matthew J.
		)	
Filed:	March 4, 2005	)	Atty. Dkt. No. NREL 02-01
		)	
Title:	Method For Achieving Device-Quality Active Layers in Lattice-Mismatched, Epitaxial Heterostructures	)	

REPLY BRIEF

To: MS Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Reply Brief is responsive to the Examiner's Answer mailed November 14, 2008. Although this Reply Brief is being filed after the 2-month filing deadline, Appellant respectfully requests that it be made a part of the record for the Board's consideration.

This Reply Brief contains items under the following headings, as recommended for reply briefs in MPEP §1208:

I. Real Party In Interest

II. Status of claims

III. Grounds of rejection to be reviewed on appeal

IV. Argument

I. REAL PARTY IN INTEREST - AMENDED

Effective October 1, 2008, the real party in interest for this appeal is the Alliance for Sustainable Energy having its principal place of business at 1617 Cole Blvd, Golden, CO 80401-3393, via an assignment by Midwest Research Institute.

The United States Government also has rights in this invention under Contract No. DE-AC36-08GO28308 (previously DE-AC3699GO10337) between the United States Department of Energy and the Alliance for Sustainable Energy as operator of the National Renewable Energy Laboratory.

II. STATUS OF CLAIMS

A. Total Number of Claims in Application

There are 30 claims pending in this application (Claims 1-30).

B. Current Status of Claims

1. Claims canceled: None
2. Claims withdrawn from consideration but not canceled: None

3. Claims pending: 1-30
4. Claims allowed: None
5. Claims rejected: 1-30

C. Claims on Appeal

The claims on appeal are claims 1-30.

III. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

The Office Action dated March 17, 2008, independently rejected claims 26 and 30 and claims 1-30 under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement. The Office Action also rejected claims 26 and 30 under 35 U.S.C. 112, second paragraph, as failing to distinctly claim the subject matter which applicant regards as the invention. The Office Action also rejected claims 1-25 and 27-29 under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent No. 5,518,934 to Forrest et al. ("Forrest") in view of U.S. Patent No. 6,229,152 to Dries et al. ("Dries"). Finally, the Office Action rejected claims 26 and 30 under 35 U.S.C. § 103(a) as being unpatentable over Forrest in view of Dries and further in view of U.S. Patent No. 6,350,993 to Chu et al. ("Chu"). Appellant requests the Board to review each of these grounds of rejection.

III. ARGUMENT

Examiner's Answer 1 (Response to Argument – Section 10):

The Examiner does not fully appreciate the relationship between lattice mismatch (f) and semiconductor alloy composition.

Appellant's Reply:

In the specification, Appellant defined the optimal lattice-mismatched heterostructure design (see Fig. 5) in terms of misfit (which is synonymous with lattice mismatch), because this terminology elucidates the invention as it relates to the relaxed lattice constants in the heterostructure changing with respect to the substrate it is being grown on. Contrary to the Examiner's assertion that "misfit" is not interchangeable with composition, the term "misfit" is indeed interchangeable with composition for a defined material and a defined substrate, as follows:

f is defined as:

$$f = [A(x)/A_s] - 1$$

where $A(x)$ is the relaxed lattice constant of an epitaxial layer as a function of composition x, and A_s is the lattice constant of the substrate.

By way of example, $Ga_xIn_{1-x}As$ is a ternary alloy of GaAs and InAs. Vegard's Law may be applied to find its relaxed lattice constant as a function of its composition as follows:

$$A(x) = xA(GaAs) + (1-x)A(InAs)$$

which is a linear weighting of the GaAs and InAs lattice constants (A(GaAs) and A(InAs), respectively) according to the GaAs and InAs mole fractions in the alloy (x and 1-x, respectively).

Substituting back into the expression for f results in:

$$f = \{[xA(GaAs) + (1-x)A(InAs)]/A_s\} - 1$$

which clearly shows that f is purely a function of the composition (x) since A(GaAs), A(InAs), and A_s are all constants. The above equation can also be inverted to express x as a function of f, as follows:

$$x = [A_s(f+1)-A(InAs)]/[A(GaAs)-A(InAs)]$$

This simple example shows how f and composition are indeed interchangeable for ternary systems.

The above example can be applied to any ternary alloy, particularly $InAs_yP_{1-y}$, which was used as the step-graded layer in the experimental InP-based heterostructures grown to reduce the invention to practice. The misfit profile shown in Fig. 5 represents a near-optimal $InAs_yP_{1-y}/Ga_xIn_{1-x}As$ heterostructure grown on InP and analyzed to reveal its characteristics as shown in Fig. 2 and Fig. 3. Specifically Fig. 2 shows near-perfect in-plane matching between the $InAs_yP_{1-y}$ buffer layer and the $Ga_xIn_{1-x}As$ active layer, due to a compositional overshoot in the buffer layer. Fig 3 shows highest minority-carrier lifetime.

Furthermore, Fig. 4 shows how the invention differs from the cited references. With a clear understanding of the relationship between misfit and epilayer composition, it is readily apparent that a compositional overshoot in the buffer layer at the end of the grade can be defined in terms of misfit (see, e.g., the buffer layer shown in Fig. 5). In fact, this is the best way to describe a generalized lattice-mismatched heterostructure, i.e., in Fig. 5 using misfit as a function of position in the mismatched heterostructure. In other words, if the misfit profile is defined for a heterostructure grown on a defined substrate, and the materials in the heterostructure are known, then the compositions of the materials are likewise defined.

<u>Examiner's Answer 2 (Response to Argument – Section 10):</u>

The Examiner maintains that there is no support for the term "compositional overshoot" in the specification.

Appellant's Reply:

Compositional overshoot is shown clearly in Fig. 3, Fig. 4, and Fig. 5. In both Fig. 3 and Fig. 4, the data are plotted as a function of the differential misfit between the buffer layer and the active layer.

Admittedly, there are some subtleties to this parameter that need to be understood clearly in order to appreciate the implications of the data in the figures. If the differential misfit is zero, then the buffer layer and active layer have the same relaxed lattice constant. However, because the buffer layer experiences residual strain after grading, the in-plane and vertical lattice constants are different. Thus, in order to affect an in-plane lattice match with the relaxed active layer, which has a target value for the lattice constant (or with the relaxed intermediate layer, if included), an appropriate compositional overshoot must be applied in the buffer layer. Otherwise, the buffer layer and active layer will be mismatched in the growth plane, and defects and strain in the active layer (or intermediate region) will result.

The above description applies equally to both tensional and compressional grades. Note that the term "overshoot" means that the grade must be compositionally extended to compensate for the effect of residual strain in order to achieve a target lattice constant in the growth plane. So, by plotting data as a function of the differential misfit, the figures clearly illustrate that the best result comes from applying the optimal compositional overshoot in the buffer layer.

In Fig. 3, for example, the highest lifetime is observed for the sample with the near-optimal amount of compositional overshoot in the buffer layer (the n = 9 sample). Note that the differential misfit is about -0.1% (i.e., non-zero). Likewise, in Fig. 4, the optimized, unstrained active layer is achieved using the same overshoot, and is clearly distinguished from the "prior art."

Furthermore, in Fig. 5, the compositional overshoot is clearly shown for the buffer layer in the near-optimal structure as the misfit (with respect to the substrate) is higher than that for both the intermediate layer and the active layer. The optimal compositional overshoot matches the in-plane lattice constant of the buffer layer to the relaxed lattice constant of both the intermediate layer and the active layer. Figure 6 is a cross-sectional depiction of how the invention works. Here it can be seen that the step below the buffer layer is mismatched to the buffer and nearly fully relaxed; the buffer layer is strained (indicated by a dilation of the vertical dimension of the boxes depicting the lattice); and both the intermediate layer and active layer show relaxed lattices and a lattice constant matched to the in-plane lattice constant of the buffer layer.

<u>Examiner's Answer 3 (Response to Argument – Section 10):</u>

The Examiner does not fully appreciate the relationship between "discouraging threading dislocation propagation" and "discouraging glide of threading dislocations."

Appellant's Reply:

Stress and strain in a material are related. When possible, as during the high-temperature process of epitaxial growth when materials are more ductile, existing threading dislocations will respond to stress by re-configuring themselves (gliding or propagating) to relieve strain in the material, thus lowering the system energy. In this context, "glide" and "propagation" are synonymous. Therefore, it is clear from an understanding of the specification that the unstrained intermediate layer discourages dislocation propagation up into the active layer.

In addition, "matching the in-plane lattice constant of the buffer layer to the relaxed intermediate region" is supported by the specification. For purposes of illustration, A is the in-plane lattice constant of the buffer layer, B is the relaxed lattice constant of the intermediate region, and C is the relaxed lattice constant of the active layer. If A matches C, and B matches C, then A matches B.

Furthermore, matching the various parameters (A, B, and C) is clearly shown in Fig. 5 and Fig. 6. Fig. 5 shows that the intermediate region and the active region have the same misfit, and both are defined as relaxed in the description. Therefore, it follows that both regions have the same lattice constant (i.e., lattice matched). The optimal strained buffer layer is defined as having an in-plane lattice constant that is matched to the relaxed lattice constant of the active layer. Therefore, A = B = C, as mentioned above. Finally, Fig. 6 depicts diagrammatically that A = B = C.

Examiner's Answer 4 (Response to Argument – Section 10):

The Examiner does not fully appreciate the distinctions between the claims and the cited references (Forrest and Dries).

Appellant's Reply:

Neither Dries or Forrest teach a method for achieving a fully relaxed buffer layer, or a grade that is truly matched to the device layers.

In addition, Forrest's definition of "buffer layer" means the entire graded layer, which is different than what Appellant has claimed. Appellant has claimed the buffer layer only as including the last layer grown in the step grade. Neither Dries nor Forrest discuss that the last layer in a grade harbors residual strain that is not relieved by dislocations.

It is important to note that the residual strain distorts both the in-plane and vertical lattice constants, an effect which must be known and accounted for if subsequently grown epilayers are to be precisely lattice matched. Appellant recognized this, and explicitly described the in-plane lattice matching required for the optimal structure. Additionally, Appellant's inclusion of the relaxed intermediate region that is matched in-plane with the buffer is a new feature for the generalized mismatched heterostructure that allows a quantum leap in the improvement of the quality of the active layer by lowering its defect concentration.

In addition, the combination of Forrest and Dries do not teach or suggest any method for discouraging the propagation of threading dislocations. The claimed relaxed intermediate region, in combination with the required in-plane matching with the buffer layer, is key to higher-quality active device layers in lattice mismatched heterostructures.

Conclusion

Appellant respectfully requests the Board to rule that the rejections of the claims are improper.

Respectfully Submitted,

Dated: January 22, 1009

By: ______________________

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PTO/SB/21 (12-08)
Approved for use through 01/31/2009. OMB 0651-0031
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TRANSMITTAL FORM

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Application Number	10/526,785
Filing Date	03/04/2005
First Named Inventor	Mark W. Wanlass
Art Unit	1792
Examiner Name	Matthew J. SONG
Attorney Docket Number	NREL 02-01
Total Number of Pages in This Submission	

ENCLOSURES (*Check all that apply*)

- [ ] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
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  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
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Remarks

Reply Brief to Examiner's Answer dated 11/14/09

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	National Renewable Energy Laboratory/Alliance for Sustainable Energy, LLC		
Signature	/MARK D. TRENNER, REG. NO. 43961/		
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Date	January 22, 2009	Reg. No.	43,961

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